

## The effect of minimal-flow inhalational anesthesia on peak expiratory flow rate

The effect of minimal-flow inhalational anesthesia

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### Abstract

**Aim:** In this study, we aimed to compare the effects of minimal (500 mL/min) and high-flow (3000 mL/min) anesthesia on the respiratory system by evaluating the peak expiratory flow rate (PEFR) and the ventilation pressure.

**Material and Method:** Forty ASA I-II patients undergoing elective middle ear microsurgery under minimal and high-flow desflurane anesthesia were evaluated for the PEFR in the preoperative and the postoperative 1st, 6th, 24th hours. Intraoperative hemodynamic parameters, ventilation pressures and the duration of extubation were also evaluated.

**Results:** There were no significant differences between the groups in terms of demographic characteristics. The duration of operation, anesthesia and extubation, intraoperative peak and plateau pressure, SpO<sub>2</sub>%, heart rate, end-tidal desflurane, MAC, and FiO<sub>2</sub> were similar. In the minimal flow anesthesia group, the MAP (69.40±6.21 mmHg) was significantly higher than in the patients receiving high-flow (61.70±4.39 mmHg) anesthesia (p<0.001). The difference between PEFR values measured at four different time points was statistically significant (time; F (3.38) = 29.696, p<0.001). The PEFR value in the postoperative 1st hour was statistically significantly lower compared to the preoperative levels and the levels measured in the postoperative 6th and 24th hours. The PEFR values of the patients in the high-flow and minimal-flow anesthesia groups were not statistically significantly different (Group; F(1.38) = 0.623, p>0.05).

**Discussion:** The effects of minimal (500 mL/min) and high-flow (3000 mL/min) anesthesia on the respiratory system were compared by PEFR and ventilation pressure showing similar results. With the current technological advances, the use of minimal-flow anesthesia combined with an effective follow-up period may have favorable effects.

### Keywords

Closed-circuit anesthesia; Inhalation anesthesia; Low-flow anesthesia; Peak-expiratory-flow rate (PEFR); Peak-airway-pressure; Plateau pressure; Desflurane

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## Introduction

General anesthesia can cause bronchoconstriction at any time from induction to the early postoperative period and affect respiratory functions by reducing the functional residual capacity (FRC), creating a tendency to atelectasis, and impairing the mucociliary activity in the airways [1-2].

As the duration of operation increases in direct proportion to fresh gas flow (FGF), the airways are adversely affected due to heat exposure and water loss; along with the increased consumption of the inhalational agents, costs, air pollution in the operating room, and greenhouse gas emissions to the atmosphere [3].

Reducing the use of FGF in inhalation anesthesia can allow achieving physiological respiration conditions close to normal levels, and the mucociliary activity is suppressed less by maintaining the temperature and humidity ratios in the respiratory system [4].

PEFR is measured with a peak expiratory-flow-meter and it indicates airflow limitation. Electronic and mechanical types of this particular device are available. The device is easy to use, and accurate measurements can be obtained in most patients over the age of five years [5]. The peak-flow-meter is a simple hand-held instrument with a mouthpiece on one side and a scale on the other side. When the air is blown into the mouthpiece, a small plastic arrow moves, scaling the air-flow rate. During the measurements, the patient is asked to breathe as deeply as possible and then exhale the air as fast and as strongly as possible. Serial measurements are usually used for monitoring responses to medical treatment in asthma and chronic obstructive pulmonary disease [5]. Among all types of pulmonary function tests, only the forced expiratory volume in the first second (FEV1) and PEFR can predict postoperative pulmonary complications [6-9].

In this prospective observer-blinded cohort study, we aimed to compare the effects of the minimal (500 mL/min) and high-flow (3000 mL/min) inhalational anesthesia on the respiratory system, by evaluating the PEFR.

Our secondary goal was to compare these two techniques for their effects on intraoperative hemodynamic parameters, peak, and the plateau pressure.

## Material and Methods

Our prospective, observer-blinded cohort study was conducted from 09.03.2017 to 09.06.2017 in Ankara Numune Training and Research Hospital after obtaining the Ethics Committee approval (E-17-1295 on 08.03.2017). Forty ASA I-II patients in the aged 18-70 years who received general anesthesia for middle ear microsurgery were included in this study. Written informed consent was obtained from the patients.

Exclusion criteria were pulmonary, cardiac, hepatorenal, neurological, and psychiatric diseases, drug use affecting pulmonary functions, anemia, possible pregnancies, known allergies, smoking, and a body mass index (BMI) >40, desaturation,  $ETO_2 < 35$ , and  $ETCO_2 > 40$  at any time during the study.

During the preoperative visit, patients were told how to use the peak flow-meter (ExpiRite Peak Flow-Meter®). The patients were asked to breathe as deeply as possible, and then to

exhale into the flow meter as fast and as strong as possible in sitting position. It was stated that their lips should embrace the mouthpiece of the peak flow-meter, they had to exhale in a single blow, and they should not obstruct the mouthpiece with their tongues during the blowing. Three measurements in series were taken and the highest value was recorded.

A Dräger Perseus® anesthesia device was used. Parameters used in the routine anesthesia monitoring were recorded during the operation. The decision for the induction and maintenance of anesthesia was made by the anesthesiologist responsible for the case. Only the patients receiving desflurane anesthesia with a mixture of oxygen and air in the fresh gas flow were observed. The monitoring data of the patients receiving anesthesia with the high (3 L/min) or minimal-flow (0.5 L/min) techniques were recorded.

The anesthesia device was tested with anesthetic gas monitor calibration and for leakage, using automated tests for each case. For standardization, the CO<sub>2</sub> scavenger was changed before each patient. The vaporizer was checked and it was ensured that it was full completely.

The mean arterial pressure (MAP), peripheral oxygen saturation (SpO<sub>2</sub>), heart rate (HR), inspiratory carbon dioxide (FiCO<sub>2</sub>), end-tidal carbon dioxide (ETCO<sub>2</sub>), inspiratory oxygen (FiO<sub>2</sub>), expiratory oxygen (ETO<sub>2</sub>), peak pressure (Ppeak), plateau pressure (Pplat), end-tidal measurement of desflurane (ETdes), and minimal alveolar concentration (MAC) in every 15 minutes of the operation and the duration of operation and anesthesia were recorded. Duration of extubation, defined as the time from turning off the desflurane to extubation, was also recorded. The PEFR was measured at the first, 6th, and 24th hours in the postoperative period.

The investigator, measuring the PEFR, was blinded to the anesthesia technique used.

## Statistical Analysis

The descriptive statistics of the continuous data have been presented as mean, standard deviation, median, and minimum and maximum values, whereas the discrete data have been presented in percentages.

In order to evaluate the differences between the two groups, the t-test or the Mann-Whitney U test was used after testing the conformity of the data to a normal distribution.

The Chi-square test was used to compare the groups for nominal variables.

To compare the repeated measurements in two groups, the Analysis of Variance to Repeated Measurements were used after testing the conformity of the data to a normal distribution. P<0.05 was accepted as the statistical significance limit.

## Results

Forty patients who underwent elective middle ear microsurgery under high-flow and minimal-flow desflurane anesthesia were evaluated (group HF, n=20; group MF, n=20).

The characteristics of the patients are presented in Table 1. Age, body mass index, gender, and ASA status were similar between the groups ( $p > 0.05$ ). Also, as seen in Table 2, duration of operation, anesthesia, and extubation, the intraoperative Ppeak and Pplateau, SpO<sub>2</sub>%, MAP, ETdes levels, Inspired Oxygen (FiO<sub>2</sub>%) and MAC values were statistically insignificant ( $p$

**Table 1.** Gender and ASA distributions in the High-Flow (HF Group) and Minimal-Flow (MF Group) groups

	Group HF		Group MF		p*
	n	%	n	%	
Gender					
Female/Male	8/12	40/60	8/12	40/60	1.000
ASA					
ASA/II	9/11	45/55	9/11	45/55	1.000

\*Chi-Square Test

**Table 2.** Comparisons between HF Group (High-Flow Anesthesia) and MF Group (Minimal-Flow Anesthesia)

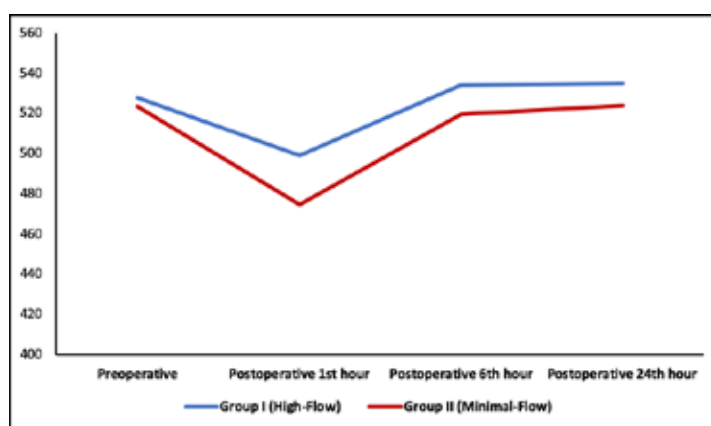
	HF GROUP ( n=20)		MF GROUP (n=20)		p*
	Mean±SD	Median (Min-Max)	Mean±SD	Median (Min-Max)	
Age (year)	43.40±12.34	43 (23-66)	37.40±13.75	34 (18-59)	0.155
BMI (kg/m <sup>2</sup> )	26.08±3.79	25.6 (21-37.3)	25.20±3.61	24.7 (20.40-32.40)	0.457
Duration of operation (min)	121.0±29.41	115 (60-170)	125.75±34.46	122.5 (60-185)	0.642
Duration of anesthesia (min)	128.75±29.99	125 (65-180)	135.5±34.79	132.5 (70-195)	0.515
Duration of extubation ± SD (min)	5.65±1.63	5 (5-10)	6:50±2.35	5 (5-10)	0.383
Mean Ppeak (cmH <sub>2</sub> O)	16.60±2.91	18 (12-20)	16.00±2.62	15.5 (12-21)	0.497
Mean Pplat (cmH <sub>2</sub> O)	14.90±3.18	17 (10-19)	14.75±2:59	14.5 (10-20)	0.871
SpO <sub>2</sub> %	99.35±1.04	100 (97-100)	99.15±0.99	99.5 (97-100)	0.478
HR (/min)	71.60±10.17	70.5 (55-94)	73.55±8.08	75 (60-87)	0.506
MAP (mmHg)	61.70±4.39	60.5 (55-70)	69.40±6.21	70 (59-80)	0.000
ET Des (%)	7.22±0.65	7.1 (6-9)	7.11±0.39	7 (6.4-8)	0.537
MAC	1.17±0.13	1.1 (1-1.5)	1.10±0.10	1.1 (1-1.5)	0.121
FiO <sub>2</sub> %	45.80±2.55	45 (42-50)	44.65±2.39	45 (40-48)	0.149

SD: Standard Deviation; Min: Minimum; Max: Maximum  
\*t-test/ Mann-Whitney U Test

**Table 3.** Comparison of the Peak Expiratory Flow Rate (PEFR) measured at different times between two groups

Group (G)	Time (T)			
	Preoperative PEFR	Postoperative 1st hour PEFR	Postoperative 6th hour PEFR	Postoperative 24th hour PEFR
Group HF	527.75±90.44	499.00±92.05	534.00±90.23	535.00±92.76
Group MF	523.50±91.84	474.50±83.06	519.50±85.31	524.00±85.19

>0.05). Desaturation did not occur in any of the patients during the study. The lowest recorded FiO<sub>2</sub> values were 42% and 40% for the minimal and high-flow anesthesia patients, respectively. In the MF group, MAP values (69.40±6.21 mmHg) were significantly higher than in the HF group (61.70±4.39 mmHg), (p<0.001).



**Figure 1.** Changes in mean PEFR over time in high-flow and minimal-flow Anesthesia Patients

G: F (1.38) = 0.246, P = 0.623, p>0.05

T: F (3.38) = 29.696, P = 0.000, p<0.001

GxT: F (3.38) = 1.279 P = 0.285, p>0.05

The changes in the PEFR values of the high-flow and minimal-flow anesthesia patients were similar. Therefore, the interaction effect was not statistically significant (GxT: F (3.38) = 1.279, p>0.05).

The difference between PEFR values measured at four different time points was statistically significant in both groups (Time: F (3.38) = 29.696, p<0.001). The PEFR value in the postoperative 1st hour was statistically significantly lower compared to the preoperative levels and the levels measured in the postoperative 6th and 24th hours.

The PEFR values of the patients in the high-flow and minimal-flow anesthesia groups were not statistically significantly different (Group: F (1.38) = 0.623, p>0.05).

Figure 1 shows the significant decline of PEFR in the first hour in both study groups. This decline was significant compared to the levels obtained in the preoperative period. There was an increase in the late postoperative period in the 6th and 24th hours compared to the 1st hour and this increase was significant. However, this change was not statistically significant compared to the values obtained in the preoperative period.

**Discussion**

The use of minimal-flow anesthesia not only maintains the temperature and humidity of the respiratory system but also minimizes the associated costs and prevents air pollution. The physiology of the tracheobronchial environment is maintained more effectively in the minimal-flow anesthesia compared to the high-flow owing to the better preservation of mucociliary clearance [4]. For this reason, low flow anesthesia is assumed to have favourable effects on respiratory functions. Several studies with different methodologies have investigated whether low-flow anesthesia has favourable effects on respiratory functions

Bilgi et al. [4] investigated the effect of low-flow (1 L/min) on mucociliary activity, humidity, temperature ratios, and spirometry. They found that the humidity and temperature ratios were significantly higher in the low-flow anesthesia. Post-op FVC and FEV1 values were lower compared to the preoperative values and they were lower in the high-flow group.

In our study, we used PEFR instead of FEV1. Nevertheless, we could not find a significant difference in the PEFR values between the minimal-flow and high-flow desflurane groups. We observed a significant decline of PEFR in the early postoperative period. These contradictory findings between the results of our study and Bilgi et al. [4] might have occurred because the mean duration of surgery was longer in the latter.

Doger et al. [10] investigated the effects of low-flow (1 L/min) and high-flow (4 L/min) sevoflurane anesthesia on pulmonary functions. FVC, FEV1, and FEV1/FVC% were measured while the patients were in the sitting position. The results of the preoperative and postoperative spirometries were similar in both groups. In all patients, FVC and FEV1 values decreased significantly at all-time points in the postoperative period compared to the preoperative values. The results of this study support our results. However, during laparoscopic cholecystectomy, intra-abdominal pressure increases, the movement of the diaphragm is limited, and FRC decreases as a result of CO<sub>2</sub> insufflation. In addition, the results of spirometry may be affected by postoperative abdominal pain

We have limited the involvement of potential medical (pulmonary diseases, obesity, etc.) and surgical factors (intra-abdominal surgery or major surgery), which may affect the PEFR, peak pressure, and the plateau pressure values [6,11] by limiting our study population methodologically, enrolling only middle ear microsurgery patients and by setting strict exclusion criteria (pulmonary, cardiac, hepatorenal, neurological, and psychiatric diseases, the patients using medications with a potential to affect the respiratory functions, the patients with anemia, a possible pregnancy, known allergies, smoking, and the patients with a BMI > 40).

The role of spirometry in preoperative risk assessment has not been clarified yet [9].

Hasukic et al. reported significant reductions in the FEV1, PEFR, and FVC in the 24th hour after laparoscopic and open cholecystectomy [12]. However, a systematic review study shows that only FEV1 and PEFR can predict postoperative pulmonary complications [13].

Stein et al. reported that PEFR was the best spirometric test to predict postoperative pulmonary complications [14].

Youngsakul et al. reported that PEFR is a simple and valuable bedside method for predicting pulmonary complications [7].

In our study, we observed a statistically significant reduction in the PEFR values regardless of the type of the anesthesia method (minimal or high-flow) in the postoperative 1st hour. However, no pulmonary complications or desaturation occurred in our patients.

Accurate measurement of PEFR using the correct PEF maneuver is obviously critical; however, some patient errors reported [8,15,16].

One of the reasons for incorrect measurement is the “spitting maneuver” of the patient, accelerating the flow of blown air with his or her tongue [15,16]. Also, position affects PEF values. Although significant differences were found between positions, suggesting the appropriateness of the standing position [17]; upright sitting position in the bed would be appropriate for the patients, who would be unable to stand up [17,18].

In our study, we performed the measurements in the sitting

position in bed because it would be inconvenient to perform maneuvers in the standing position in the early postoperative period. Therefore, we obtained low PEFR values in contrast to the estimated values by age, gender, and the body-weight. However, since our goal was to monitor the course of PEFR values according to the type of anesthesia, we performed the measurements in alignment with the recommendations of McCoy et al. [18].

Postoperative respiratory failure can occur due to several factors associated with anesthesia and surgery including obesity, incision site, tight dressings, gastric dilatation, postoperative pain, and residual effects of anesthetics. All these factors may cause critical respiratory events such as upper airway obstruction, pulmonary aspiration, atelectasis, and pulmonary consolidation [19]. Postoperative residual neuromuscular curarization (PORC) also may be an important cause of respiratory weakness, characterized by a restrictive breathing pattern in the early postoperative period. PORC leads to a decrease in the FVC and the PEFR postoperatively, indicating impairment of respiratory muscle function [22].

In our study, the underlying reason of the PEFR reductions observed in the postoperative first hour can be PORC. However, the lack of Train-of-four (TOF) monitoring is a limitation of our study, preventing conclusions.

A second possibility for an early postoperative PEFR decline may be an insufficient recovery. However, the characteristics of recovery from sevoflurane and desflurane are faster compared to other inhalation anesthetics [21,22].

The effects of the minimal-flow anesthesia involve the parts of the anesthesia machine before the Y part. The connection point of the machine has a tube/ring system. This means that if minimal-flow anesthesia is successfully used in a patient, it will never cause changes in pulmonary functions compared to high-flow anesthesia. The minimal-flow anesthesia method normally affects only the amount of waste gas [10].

However, possible disadvantages that may arise from the improper use of minimal-flow anesthesia include hypoxia, excessive or insufficient concentrations of volatile substances, hypercapnia, and the accumulation of potentially toxic gases.

Sivaci et al. [23] compared low-flow (2 L/min) sevoflurane and desflurane anesthesia in 26 patients, who underwent elective laparoscopic surgery. They observed a progressively significant increase in the peak pressures and respiratory resistance in the desflurane group. No changes were observed in the sevoflurane group. Positional and procedural characteristics of laparoscopic surgery may be involved in the emergence of these differences. Furthermore, it is not clarified yet whether the increases in peak pressures and resistance and the decrease in dynamic compliance have any clinical consequences or impinge on the postoperative complications.

Another study did not show a significant difference between the baseline airway pressures and resistance at 1 MAC for the first 30 minutes. However, despite the uncertain clinical significance, decreasing pressure and increased resistance have been observed with the turning off of the gas at 1.5 MAC [24]. Desflurane has been reported to increase cytokine expression in alveolar macrophages and cause a higher level of pro-inflammatory response compared to sevoflurane.

However, Kalaycı et al. reported that there was not a significant difference in the IL10 levels between the low-flow and high-flow desflurane anesthesia [16,25].

In our study, resistance and dynamic compliance could not be measured. However, no significant increases were observed in peak and plateau pressures during surgery in the study groups. There were no significant differences in the peak and plateau pressures between the groups. Since the patients were given remifentanyl infusion, their MAC levels were as low as  $1.17 \pm 0.13$  and  $1.10 \pm 0.10$  for high-flow and minimal-flow anesthesia, respectively.

Although there are limitations in our study, the results became more robust due to the methodological elimination of the patient and surgery-related factors which may have effects on PEFr and pressures. The second limitation of our study is the limited number of patients. It is possible that different results may be obtained in longer surgical interventions and larger-scale studies.

### Conclusion

There were no differences in PEFr, the peak and plateau pressures, and duration of extubation between the minimal-flow (0.5 L/min) and high-flow (3 L/min) groups. With the current technology, the use of minimal-flow anesthesia combined with an effective follow-up period may have favourable effects on respiratory functions as well as economic and ecological benefits.

### Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

### Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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### Conflict of interest

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